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Multiple Paths in Complex Tasks

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Introduction

This study examines whether the composite utilities of alternative paths to a goal can predict the chosen route. "Paths to a goal" are the behavior choices one makes while pursuing a valued task when there are optional routes. For example, a pilot flying from New York to Los Angeles may bypass a storm by flying north or south around the build-up. Often it is the case that there is no unique optimal strategy in pursuing a task. Rather, one makes judgments at various points that are demanded by exigencies of the task or perhaps by extraneous events.

The utility of an alternative path may be based on evaluative rather than cognitive functions. Feelings color judgment. Usually one construes the choice of sub-tasks as constrained by some overall calculus of cognitively derived utility. However, various routes to a goal may tend to derive their values from affective components weighted by cognitive calculations. If the choice between paths has little cognitive consequence, it may be fair game for feelings and desires. Consequently, predictions of task performance can err if they rely only on cognitive computations. Valuable considerations may contribute significantly to the gross numerical evaluation of the effort.

The utility of the entire decision path of a complex task refers to its net positive and negative attributes from whatever their source which are considered in order to maximize some unitary criterion. This conceptualization accords with commonly accepted definitions of utility (Luce and Raiffa 1967). In the case of a complex task and its corresponding sub-tasks, the assumption is that the criterion is some measure, e.g., minimum effort, for the completion of the task. At present we cannot easily distinguish on the basis of behavior alone between those utilities that contribute to the total value of the task goal that are primarily cognitive, and those that are suffused with emotive weight. In part the experiments that follow are aimed at helping to define behavioral criteria to separate these components.

The present study is a refined extension of work whose beginnings were reported in Semi-Annual Progress Report No. 1, dated 15 July 1986. In this experiment we examine the relation between utility judgments of sub-task paths and the utility of the task as a whole. This is a convergent validation procedure (von Winterfeldt and Edwards, 1986). It is based on the assumption that measurements of the same quantity done with different methods should covary. In other studies convergent validation procedures showed high correlations (von Winterfeldt and Edwards, 1986). Using workload and stress ratings, Hart and Bortolussi (1984) demonstrated the robustness of convergent validation techniques. Significant correlations occurred between the combined sub-task ratings and the total ratings in a flight scenario. Various kinds of measurements used in complex task performance that were found to be significant indicators of workload included performance on a secondary tasks (Ogden et. al., 1979), the event related brain potential (Isreal et. al., 1980; Kramer and Wickens, 1983), and subjective rating techniques such as category scales (Hart et. al., 1981), magnitude estimation (Borg, Gunnar, 1978), and Cooper / Harper subjective ratings (Wierwille and Connor, 1983). Because the implicit precision of

ratio scaling methods has been demonstrated in laboratory experiments, and because these methods suggest combinatorial models with special constraints, we shall use magnitude estimation as the data base.

A significant relation between sub-task and whole task utility judgment may lead to practical consequences. First, the experimental decomposition of a complex task into measurable components could be used to find optimal task paths. Sub-task paths of high utility could be identified. Low utility paths could be discounted. A second advantage is based on the argument that component ratings (if they could be combined) would provide a better sense of one's underlying values than overall judgments. This view assumes that evaluating components requires more time and introspection (von Winterfeldt and Edwards, 1986). Third, a model that combines sub-task ratings also provides information on how each sub-task contributes to the variance of the total task utility. Finally, a significant relation between sub-task utility and total task utility makes it possible to predict alternative path choices. If, for example, a high utility path is blocked, we may expect the path with the next highest utility to be chosen.

The utility measures of our sub-tasks were obtained during the performance of an "aircraft flight controller" navigation task. This task had been divided by the experimenter into two discrete sub-tasks. On successive trials, subjects use three different alternatives to reach the the first sub-task goal. The second sub-task, also exposed them to three different alternatives to reach that goal. Thus, there were nine possible combinations of paths all of which lead to the task goal. During each sub-task, the subject rated the utility of each path relative to a numerical modulus. The experimenter then asked the subject to rate the utility of the combined choices relative to reaching the criterion—the task goal.

Analyses helped us decide among various models of sub-task utility combination, whether the utility ratings of sub-task paths predict the whole task utility rating, and indirectly, whether judgmental models need to include the equivalent of "cognitive" noise.

Preliminary models

Based on concepts drawn from psychophysical scaling experiments, (Stevens and Galanter, 1957), a log transformation model of the relation of sub-task utilities to total task utility is conjectured. This model in simplest form is:

$$\log U_t \geq \sum_n [w_i \log (u_i)] \quad [1]$$

where

- U_t = the utility of the strategy used to complete the task;
- u_i = the utility of the strategy used to complete sub-task i ;
- n = the number of sub-tasks that the task is decomposed into;
- w_i = the weight assigned to sub-task i in the combination rule.

This relation is proposed as a fair approximation of how sub-task utilities are combined. It is based on the assumption that the reported utility of non-monetary events is a power function of perceived value (Galanter 1987). Another plausible conjecture is an

additive model using untransformed data, We shall contrast this model with its logarithmic alternative:

$$U_t \geq \sum_n [w_i u_i] \quad [2]$$

Both models make three assumptions. First, it is assumed that the subject is interested in maximizing some criterion. The criterion we presume that the subject is maximizing is achieving the task goal with minimum effort and failure. Second, since an additive relation is proposed, the corresponding assumption of path independence is assumed. Path independence assumes that the choice made to reach the goal of sub-task i do not affect choices for other sub-tasks. This assumption can be validated by testing whether the interaction between path choice utility ratings is zero. The third assumption of the model is that the combination rule should be invariant with respect to the path chosen, as long as the sub-task goals and task goals remain constant. This assumption can be tested by determining whether the fit of the model for each path combination remains invariant.

The first model proposes that the log of the sub-task utilities have a linear relation to the log of the task utility. The theory of the model is based on two types of empirical results which suggest that the relation of two subjective magnitudes whose forms are power functions is linear when plotted in log log coordinates. Judgments of stimulus magnitude generally follow the form of a power function when ratio estimation techniques are used. This phenomena holds across a variety of judgments including length, weight, loudness, brightness (Stevens and Galanter, 1957), money (Galanter, 1962; Kornbrot et. al., 1981) and non-monetary events (Galanter, 1987). Cross-modality matching experiments of utility of monetary and non-monetary events show that the two subjective magnitudes whose forms are power functions follow linear relations in log-log coordinates (Galanter and Pliner, 1974). Here, we anticipate that sub-task utilities and task utility assume the form of a power function. Thus, the relation of the log of the subtasks' utility to the log of the task utility should be linear, consistent with the magnitude estimation studies and the cross-modality matching results.

Utility estimation.

A central assumption of all subjective rating methods is that the subject's numerical reports represent quantitative information about their experience. Two important criteria that subjective rating techniques should address are sensitivity to subjective experience, and invariance with respect to irrelevant variables. Direct scaling techniques have demonstrated that it is possible to scale the value of money and the subjective probability of uncertain events. As a check on these judgments, the subject's choice between two alternatives was then predicted based on determining the events' subjective expected utility (Galanter, 1962). Invariance in the utility response of money was demonstrated in a signal detection task where the payoff matrix was multiplied by a constant and the signal presentation probability was varied (Galanter and Holman, 1967). These experimental manipulations did not alter the subject's utility estimates. Utility judgments were found to effectively represent gains and losses of money as well as the value of money (Galanter and Pliner, 1974). The utilities for non-monetary events have also been shown to correspond closely to utility judgments for monetary events using a magnitude estimation technique (Galanter,

1987). The direct scaling of utility therefore seems appropriate to assess the path utilities in this experiment by satisfying the criteria of response invariance and subjective sensitivity.

The shifty modulus

Magnitude estimation methods normally require that averages be struck across a sample of subjects. The reason is that asking a subject to assess repeatedly the magnitude of the same stimulus display leads to the simple repetition of his judgment. In order to circumvent this tendency, and to permit magnitude estimates from a single subject, we have developed a judgmental technique called the "shifty modulus" (Galanter 1987b). This procedure obtains repeated utility estimates with reference to a set of moduli, each with a different announced value. Subjects rate the utility of the path they chose in comparison to a standard path to which different numerical values are assigned on successive trials.

The Experiment

The experiment itself is a simulation of an air traffic controller's task. In this task the controller must first choose a display method for the air traffic, and then choose a procedure for conflict resolution. The overall goal is to maintain safe traffic separation for the aircraft. The specific goal in stage 1 is to choose a method to display altitude information. Stage 2 models some features of the decisions air traffic controller's make. These include scanning for potential collision and then taking remedial action. The task in this stage is to choose a method for changing the flight path of a target to prevent collision. The subject is told that at least one potential collision will occur on each trial.

Subjects

Five paid subjects, all students at Columbia University, participated in the experiment. Four of the subjects were male. The student ages ranged from 19 to 26. They all had vision correctable to normal.

Apparatus

The program (see Appendix) was run on a Commodore Amiga microcomputer. Subjects were seated in a well lighted laboratory at a console containing a keyboard, a pointing device (mouse), and a color CRT. The subject was free to adopt a comfortable position facing the screen within reach of the keyboard. The subjects generally chose a position that placed their eyes slightly above and 20 inches distant from the CRT. For their control responses, subjects used the mouse and the keyboard.

Stimuli

The design of the air traffic display was modelled on the radar scopes used by air traffic controllers in 1986. Our display in particular was based on a site visit in March, 1986 to the TRACON air traffic control facility in Westbury, New York. This is a terminal radar approach installation that monitors aircraft outside a five mile radius from each of four major New York airports: Kennedy, LaGuardia, Islip, and Newark. Radar at that facility is monochrome and vector drawn, but also contains digital alphanumerics associated with the radar returns from aircraft transponders.

Aircraft: Depending on the trial, 4, 8, or 16 white dots (approximately 8 mm in diameter) representing airplanes, move across the CRT display in piecewise linear paths. The targets move within an XYZ coordinate system. The display is construed as perpendicular to the Z axis. Alongside each dot is a smaller directional dot, approximately 2 mm in diameter, which provides information on the direction of the plane's flight vector. Tracking along with each aircraft is a two letter identification code, such as "CO." At the beginning of each trial the planes start from different positions in the display. The rate of positional change varies across planes from one pixel per frame to twelve pixels per frame, but each plane moves at a constant rate. The planes blink off about every six seconds and reappear about one second later in an updated position, paralleling the timing, but not the decaying appearance of a radar scope. The background color of the screen is dark grey.

Altitude information: Three choices are available to the subject for the display of altitude information: alphanumeric, voice, and digital meters. In the alphanumeric mode, altitude information appears beside the identification code of each aircraft. This altitude information is in the form of a one, two or three digit number which represents hundreds of feet. Voice interrogation is done by clicking the mouse over the plane in question. A synthetic computer voice responds with the plane identification code and a three digit altitude reading. The third altitude method, digital meters, displays a column of plane identifiers, alongside of which a three digit altitude number is displayed. The altitude displays are updated every six seconds along with the aircraft positions.

Changing flight vector: Subjects could change the course of one of the planes to avoid a collision by one of three methods: altitude change, continuous lateral direction change, or limited (12°), lateral direction change. Altitude change increased or decreased the plane's altitude by one thousand feet. Continuous lateral change changed the plane's direction, left or right, by 6° per frame. 12° lateral change changed the plane's direction, left or right, by 12° only once.

Experimental Design.

The nine choice combinations were assigned to each flight scenario in a Latin Square design. Twelve flight scenarios were randomized within each cell. A trial consists of one flight scenario. The 12 flight scenarios were all different and consisted of four scenarios each of 4 planes, 8 planes, and 16 planes. The data from this experiment consisted of nine cells (108 trials per subject). The experiment yielded a data matrix as follows:

		Stage 1 choice		
		<u>1</u>	<u>2</u>	<u>3</u>
Stage 2 choice	1	12	12	12
	2	12	12	12
	3	12	12	12

Each cell contains observations from the 12 different flight scenarios. Each observation consists of the utility estimates reported for subtask 1, subtask 2, and the overall task.

Practice session: Subjects first read a written description of the experiment at their own pace. The altitude and collision avoidance methods were demonstrated to the subject in the first hour. During the next three hours the subjects performed 36 practice trials to gain familiarity with the system. At this time the modulus (or standard) altitude and collision avoidance methods were also demonstrated.

Utility estimation: A ratio estimation technique using a modulus was employed for scaling the utility of the choice made. In Stage 1, the subject was asked to compare the modulus procedure for representing altitude to the method that was currently being used. The experimenter questioned the subject, "Is your choice more useful than the modulus? If so, how many times more useful than the modulus? Is your choice less useful?", etc. The subject was then asked to assign a value, relative to the modulus, that accurately reflected the utility of his or her own choice. This procedure was repeated when collecting the utility reports in Stage 2 and in the overall task. Subjects were told that no restrictions were placed on their scale and they were free to use fractions if they needed to. As we shall see however, it is not clear that all subjects understood the nature of the judgments that were being asked for. In hindsight it appears that a pre-training session on magnitude estimation would have been helpful.

Modulus formats: A coincident altitude color detection system was used as the modulus in Stage 1. In this system, any two planes attaining the same altitude changed from white to red. In Stage 2, the modulus format for collision avoidance was velocity change, which either halved or doubled the rate of pixel change per frame. If the shifty modulus technique is valid, then the utility ratio should be invariant when the modulus value is changed (Galanter 1987c). Baird and Noma (1978), suggest that the numbers based on magnitude estimation should simply be multiplied by a constant if the modulus value is changed. To test this assumption, the values of the modulus procedures were changed for each session. The numbers used were those which (the experimenter felt) could be easily doubled, halved, tripled, etc. Of this collection of numbers, one number was randomly assigned as the value of the modulus procedure of Stage 1, a second number was assigned to the modulus of Stage 2, and a third number was assigned to the combined moduli procedures as they would be used in the whole task. Three examples of moduli values for Stages 1, 2, and overall task are 3000, 5000, 150; 30, 200, 60; and 600, 50, 300.

Data Collection.

The raw data obtained from this experiment consisted of disk files created by the simulation program. Each time the subject entered a response on the keyboard or "clicked" a selection with the mouse, the time and response code was entered into the file corresponding to that session. After 36 practice trials the subjects were scheduled for 9 sessions of 12 trials per session (108 trials total). The actual yield was somewhat less than 108 trials per subject because of occasional software failure and the termination of subject E after 6 sessions.

Working files were later compiled from the raw data according to the following scheme. Each trial was encoded as a line consisting of:

subject code, scenario code, trial number, session number,
altitude display choice, reported display utility, modulus
display utility, collision avoidance method, reported avoidance
utility, modulus avoidance utility, reported overall utility,
modulus overall utility, success/failure code.

We then performed the analysis on this data set.

Procedure

All targets originated at different positions on the CRT display and moved in different vector paths. During the third frame (about 21 seconds) a window appeared on the display prompting the subject to implement an altitude display method. The experimenter told the subject which method to use. The subject then selected the prescribed method using the mouse. During the tenth frame (70 seconds), a window appeared requesting the utility estimate for that format. The value assigned to the modulus was also presented in this window. Upon consideration of the utility of the current display method, the subject entered his estimate. The subject continued to monitor the screen for a possible collision of two aircraft. On the 16th frame (112 seconds) a window appeared prompting the subject to select a collision avoidance method for future use. The experimenter told the subject which method to select. The subject was free to implement the selected collision avoidance method at any time after the prompt window was closed. The subject did this by using the mouse to select a direction (e.g. right or left, increase or decrease). The subject then typed in the two letter identification code of the plane which was to be affected. The screen flashed briefly on frame 22 to alert the subject to implement collision avoidance if it had not already been done. On the 23rd frame (161 seconds) a window appeared requesting a utility estimate for this collision avoidance method. The subject typed in a response on the keyboard. If the outcome of the collision avoidance choice was successful, the planes continued on their new flight vectors. If the outcome resulted in a crash of two planes, a message flashed on the screen indicating that "a fatal air collision has occurred." On frame 24 (168 seconds) a window appeared prompting the subject for a total task utility judgment. The subject typed in a judgment of the overall utility of the two methods used in performing the task. The rating was made relative to how well the two modulus procedures would have worked in completing the task.

Results

The utility estimates collected in this experiment were subjected to both a logarithmic and a linear regression analysis. However, before we performed the regressions, some preliminary transformations and tests were done to check the basic assumptions of modulus and path invariance. After demonstrating that modulus invariance holds, we converted the utility estimates into relative utility estimates for the sake of easy comparison across trials with differing modulus values. This simple conversion consists of dividing the reported utility value by the modulus utility value.

A preliminary analysis of the data revealed that only two of the subjects, C and D, used the ratio method to rate their subjective utilities. Subjects B and E appear to have used a category type judgment in their reports, indicating that they did not understand the verbal and written instructions provided at the beginning of the experiment. The randomness evident in subject A's utility reports reveals that this subject used neither a ratio method nor a category method in evaluating the choices. This apparent lack of method might possibly be due to a perceived equivalence among the choices.

The method employed to determine which rating system a subject used is based on the assumption that the noise, or "scatter," in the reports is symmetrically distributed about the mean. Under the appropriate transformation i.e. logarithmic for ratio, linear for category judgements, the scatter should become symmetrical. The symmetrical noise criterion can be justified by showing that the subject's biases and uncertainties undergo the same internal transformation as the "signal" we measure. Because ratio and category judgments are both modulus comparisons, the sources of noise in both judgmental modes are presumed similar. An algebraic argument is presented in the Appendix.

This technique of "linearizing" noise in order to decide whether the subject made category or ratio judgments becomes clear when the data are viewed graphically. Figure 1 shows the idealized result of the inferred category or ratio judgments transformed either linearly or logarithmically. In Figure 2, data from two subjects who arguably used different judgmental modes are displayed. These graphical representations support the assumptions outlined above.

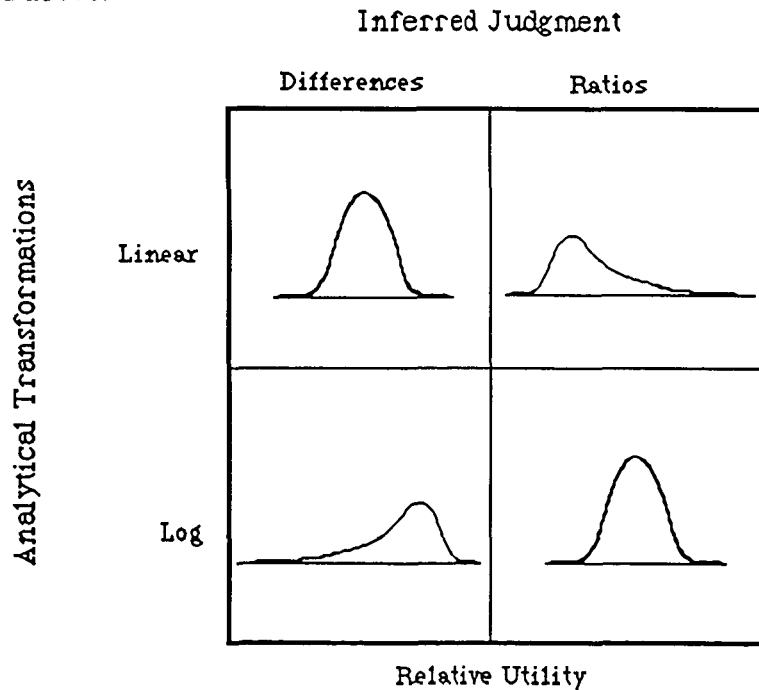


Figure 1

Although the data from subjects A, B, and E must be ignored when determining the relationship between the sub-task utilities and the overall utility, their data can still be used to test the assumptions of path and modulus independence.

Statistical analysis: Different modulus values were used for each sub-task and session in order to circumvent the bias due to past utility rating reports. By varying the modulus values we are making the assumption that the value of the modulus does not affect the subjects utility estimates. This assumption was tested with the General Linear Models (GLM) procedure of SAS which handles unbalanced designs. The means for each variable were tested to see whether they differed significantly between sessions. Each session used three different modulus values. The assumption was violated for subject A whose mean utility estimates were significantly different for sub-task 1, sub-task 2, and task variables, with $p < .05$. Subject B had significantly different means for his utility estimate of sub-task 2 across sessions. The remaining subjects did not show significant differences between their utility estimates when different modulus values were used over sessions.

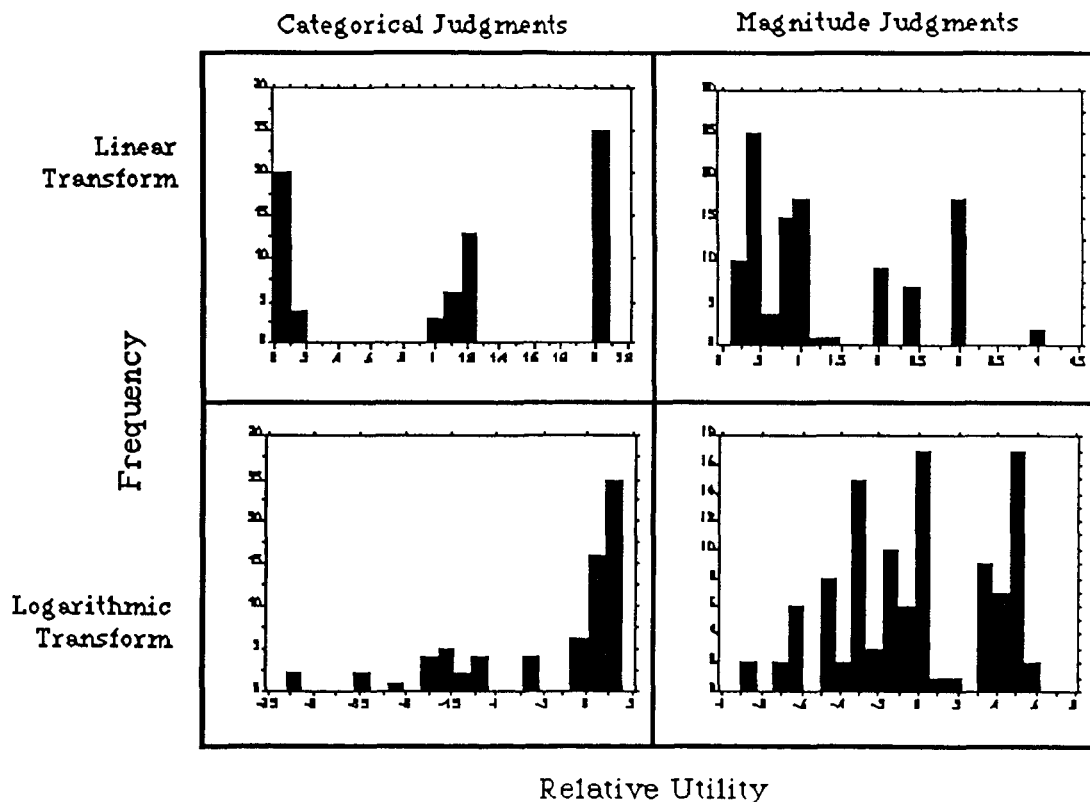


Figure 2

The mean utility estimates for subjects are shown in table I. Subjects C, D, and E usually gave utility estimates that were significantly different between the paths in sub-task 1 and 2. Subject A did not differentiate between the choices based on the ratings shown.

Subjects were generally consistent in rating voice interrogation with the lowest utility and alphanumerics as having the highest utility. In sub-task 2, subjects were generally consistent in rating 12° lateral change with the lowest utility and altitude change with the highest utility.

Table I
(Entries Represent modulus ratio)

Subject	Sub-Task 1			Sub-Task 2			Total Task
	A-N	V-R	D-M	A-C	12°	LC	
A	2.72	2.28	2.42	2.46	2.20	2.29	3.02
B	1.26	0.72	0.74	1.30	1.19	1.29	1.52
C	1.44	0.90	1.30	1.36	0.97	1.20	1.21
D	2.58	0.54	0.79	3.32	1.23	2.03	1.87
E	2.00	0.05	1.16	1.82	0.54	1.11	1.18

Sub-Task 1: A-N=Alphanumerics; V-R=Voice Report; D-M=Digital Meters Sub-Task 2: A-C=Altitude Change; 12° = 12° Lateral Change; LC=Continuous Lat Chg

If the model is correct, the form of the prediction equation should be the same for all subjects, although the weights assigned to each sub-task may vary over subjects. A multiple regression analysis was performed on each subject's data. The dependent variable is the overall utility estimate of the combined path choice for both sub-tasks, and the independent variables are the sub-task 1 utility estimate and the sub-task 2 utility estimate. The model that was tested is of the form:

$$\log(Y_i) = a + b_1 \log(X_{1i}) + b_2 \log(X_{2i}) + e_i \quad [3]$$

The results of the regression analysis are shown in Table II. The asterisks refer to whether the beta coefficients of the intercept and sub-task utilities are significant.

Table II
Beta Estimates

Subject	N	Intercept	Sub-Task 1	Sub-Task 2	p—Value	
A	95	0.2281	0.2829	0.7483	0.0001	0.7971
B	92	0.4118*	0.2790*	0.0324	0.0197	0.0845
C	105	0.1164*	0.0906*	0.3406*	0.0001	0.3343
D	99	0.1174*	0.5176*	0.9215*	0.0001	0.8211
E	59	0.1675*	0.1707	0.5379*	0.0001	0.7751

*Significant at $p < 0.05$ Mean $R^2 = 0.5624$

Four out of the five subjects gave subtask utility estimates that were predictive of the overall utility according to the model specified in [3]. Subject B's utility estimate for the

paths used in sub-task 2 was not significant.

The percentage of variance explained in the total task judgment, R^2 , ranged from values of .08 to .82. Models fit for three subjects, A, D, and E explained more than 77% of the variance of the holistic task judgment. Subject B's model shows an R^2 close to zero, and subject C a moderate value R^2 value, explaining 33% of the variance of the holistic task judgment. The residuals plotted against the predicted values for each subject show the residuals to be evenly distributed around zero indicating that the equal variance assumption of the error terms for the model appears to be met. They also indicate that the fit of the log log model is appropriate.

Next, a strictly additive model was tested to compare the fit with the fit obtained in the log transformed model. This type of model is of the form:

$$Y_i = a_i + b_1X_1 + b_2X_2 + e_i \quad [4]$$

The level of significance of beta parameters for the stage utility estimates are shown in Table III.

Table III

Subject	N	Intercept	Beta Estimates		p—Value	R^2
			Sub-Task 1	Sub-Task 2		
A	95	0.0841	0.2096*	1.0516*	0.0001	0.7770
B	92	0.6953*	0.4399*	0.3343*	0.0015	0.1368
C	105	0.5868*	0.1665*	0.3559*	0.0001	0.2872
D	99	0.5286*	0.6868*	0.7156*	0.0001	0.8013
E	59	0.0248	0.5146*	0.5483*	0.0001	0.8456
*Significant at $p < 0.05$					Mean $R^2 =$	0.5695

Subjects A, D, and E show that the model explains more than 77% of the variance of the total task judgment. All beta estimates for the slopes are significant for both variables. In order to explain certain anomalies in these data it will be useful to have the range of utility estimates available, as contained in Table IV.

Table IV

Subject	Subtask 1			Subtask 2			Whole Task		
	Min	Max	Range	Min	Max	Range	Min	Max	Range
A	0.75	6.00	5.25	0.38	4.50	4.19	0.67	6.50	5.83
B	0.50	1.70	1.20	0.02	1.93	1.50	0.75	2.25	1.50
C	0.03	2.50	2.47	0.40	2.50	2.10	0.71	2.50	1.79
D	0.13	4.00	3.88	0.50	4.00	3.50	0.25	4.44	4.19
E	.001	2.00	2.00	0.10	2.00	1.90	0.20	2.40	2.20
All Subjects	0.001	6.00		0.02	4.50		0.20	6.50	

The largest range in utility estimates for any individual subject is 5.83. The average range over all subjects for all estimates is 2.90 with a standard deviation of 1.46. The ranges suggest that subjects imposed reasonable upper and lower bounds on their estimates.

In order to validate the assumption of path independence, the interaction between the subtask utility estimates was tested for significance. A third alternative model was tested of the form:

$$\log Y_i = a_i + b_1 \log X_1 + b_2 \log X_2 + b_3 \log X_1 * \log X_2 + e_i \quad [4]$$

When a partial F test was performed, placing the first two terms in the model, the interaction term was not found to be significant for four subjects. For subject D, the interaction term was significant with $p < .01$. When an overall F test (simultaneous test) was performed, the interaction term was not significant for all subjects except D.

It follows from the prediction equation that the inter subject difference would exceed the intra-subject difference. The form of the prediction equation should be the same for all subjects but the parameters could be different. Using a dummy variable model, the additive model shows significant differences between subjects with $p < .0001$, proving this prediction to be true.

The third assumption of the model stated that the combination rule for sub-task utilities should be invariant with respect to the choices made. The model was tested for significant differences for each of the path combinations. Nine different path combinations were used. Approximately twelve ratings were made for each of the nine path combinations. Subject D did show a significantly different model over path choices, as shown in the slope estimate for his sub-task 1 utility, with $p < .01$. All other subjects satisfied the assumption.

Multicollinearity.

Two tests were performed to determine whether multicollinearity existed in the data. First, a correlation matrix was computed for each subject to determine whether the independent variables were correlated. Only subject A showed a significant correlation with $r = .34$. Bohrnstedt and Knoke (1982) suggest as a rule of thumb that variables with correlations higher than $r = .8$ should be considered to inflate the error term excessively. A tolerance test using the additive model was conducted to determine whether this amount of correlation would excessively inflate the error term. Based on the value of the coefficient of determination, the variance would be inflated by a factor of 1.1296. From these considerations, we conclude that multicollinearity is not serious enough to warrant remedial action.

Discussion

Four of the five subjects' data showed a significant relation between their judgments of the utility of the component sub-tasks and overall utility judgments. Unfortunately, only two of the subjects used the ratio judgement procedure in reporting the utility of the various choices. Because of this, conclusive evidence showing the validity of the log model was

not obtained. Nevertheless, our data does show that path invariance holds. What is also important to note is that the results occurred despite the fact that the modulus values were different for all three estimates indicating that modulus invariance holds also.

The mean R^2 of .5695 is about the same for both the log log model and simple additive model. One reason for the similar fit of both models is that the range of the utility estimates is not very large (Table IV). It is not possible to differentiate whether a power function or linear function provides a better fit based on the data obtained in this experiment. Within the narrow range of values of the data, the power function appears close to being linear.

The log transformed data in an additive model cannot be argued for merely on statistical grounds, but it can be supported on theoretical grounds. The magnitude estimation and cross-modality matching studies suggest that the relation of two subjective magnitudes should appear linear in log log coordinates. The way to provide a stronger test of the proposed model would be to collect data on subjective utility estimates that extend over a larger range of values. One way to accomplish this is to present path choices that would generate more extreme utilities. The path choices in this experiment were not regarded as significantly different by two subjects. This may have resulted in a low range of utility estimates.

The result showing that subjects B and C have different models over sessions (where each session has different modulus values) is quite significant. This outcome could explain why subjects B and C have low R^2 values. Subjects B and C could have the potential to be consistent in component-to-task ratings but may be influenced by the different modulus values. The evidence to back up this claim is that subject C had models from three sessions that accounted for over 63% of the variance and subject B showed two models that accounted for over 35% of the variance. More subjects are needed to determine whether subject B, whose R^2 was .08, is an anomaly.

It is possible that subjects B and C were internally consistent yet performed poorly because they were confused by one path choice. Models were fit for the three levels of sub-task 1 choices, over all levels of sub-task 2. Models were also fit for three levels of sub-task 2 choices over all levels of sub-task 1. Models for subject B did not yield an R^2 higher than .20 for any of the six path choices. Subject C did not show an R^2 for any path choice higher than .37. Thus, it is unlikely that confusion about a path choice would be the cause of a low R^2 .

If we eliminate subjects B and C from the mean R^2 , since they are inconsistent over sessions, we find that the mean R^2 for the additive model is now .81. Because of several sources of variance that exist in the nature of this experiment, this mean R^2 of .81 is quite good. Several components are involved in the decision making process, each of which could potentially contribute a source of variance to the utility estimate. There is a source of variance associated with the perception of the visual display, a source of variance associated with the decision involved in choosing an option, and a source of variance associated with assigning a number to represent one's utility judgment for that option.

These three components of the decision making process are repeated in sub-task 1 and sub-task 2 of the task. The overall utility rating also has variance associated with assigning a number to it.

In a test of the means, subject A violated the assumption that the modulus value does not make a difference in the utility estimate. However, subject A's model is invariant over sessions. This latter test can be considered a stronger test in that it utilizes all levels of the independent variables.

Subject D showed a significant interaction term. With this term included in his model, the R^2 for subject D is .8236. This represents a marginal contribution of 2% over the additive model in explaining the variance of the judgment. Based on these results, it does not appear that the interaction model offers a better explanation of the variance of the task judgment. Thus, we conclude that the path independence assumption is reasonably satisfied.

Four of the five subjects showed an invariant model over path choices. This phenomenon shows the robustness of the internal consistency. The subject generally applies the same weighting regardless of whether the choice is good or bad. In order to test this assumption of the model, the experimenter had to assign choices to the subject; otherwise, the subject may never have picked a path of low utility. The model is also robust with respect to success or failure of the outcome. This result may indicate that in the case of failure, the subject may assign responsibility to extrinsic factors.

The experimental design showed a failure to construct displays that would elicit ratings revealing different levels of difficulty. Thus, we cannot establish the robustness of internal consistency in complex tasks involving varying levels of difficulty. None of the subjects experienced difficulty in providing a numerical estimate of their utility using the modulus. In general, all subjects reported that their utility estimates closely reflected the utility of their choices.

The air traffic controller's (ATC) goal is to work within the capacity of his information processing resources so as to maximize decision making performance. If this capacity is exceeded, poor decision making can result. In terms of this study, we predict that one of the consequences of exceeding capacity limitations could be a decrease in the internal consistency, or predictive quality, of the utility ratings. It would be interesting to test this prediction by introducing a variable in a future study that could be shown to increase stress level.

Danahar (1980) discusses two air collisions due to poor decisions of the ATC. A crash of two commercial carriers over Carlton, Michigan in November, 1975 occurred due to the ATC's decision not to take immediate action. In another case study, the ATC failed to maintain vertical or lateral separation resulting in the collision of a commercial and private aircraft near San Diego in September, 1978. Finkelman and Kirschner (1980) propose that decision failure is due to the ATC working for an extended period of time using "reserve capacity." The overworked ATC is thus unable to process information adequately when an

emergency arises. An alternate model by Sperandio (1978) proposes that the strategy of the ATC changes as more information is introduced. As more aircraft appear on the screen, fewer variables per aircraft are processed. In studying memory errors in the ATC–pilot communication, Loftus et. al. (1979) showed that memory load and retention interval were significant factors.

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Appendix

Making response distributions symmetric

In noiseless category judgments (Stevens and Galanter, 1957) the reported sensation (utility in this context) is based, presumably, on the subjective differences between the judgmental object and the modulus:

$$\text{category judgment} \approx f(\text{object}) - f(\text{modulus})$$

Noiseless magnitude estimations yield numerical responses based on a subjective ratio:

$$\text{ratio judgment} \approx f(\text{object}) / f(\text{modulus})$$

We may view this as a difference in the logarithmically transformed values:

$$\log(\text{ratio judgment}) \approx \log(f[\text{object}]) - \log(f[\text{modulus}])$$

In this experiment the objects of judgment occur at a high level of abstraction and consequently are subject only to minimal amounts of sensory or perceptual noise. At this level of observation, the only source of error is probably a response or other post-stimulus bias; a common mode noise. This bias is presumed to affect judgments of the object of interest and the modulus.

The second component of the noise or error that occurs in a comparative judgment may be attributed to differences in the way the object and the modulus are perceived. The object being judged is interpreted as a perceptual event, whereas the “replay” of the modulus may be shifted by the accumulated effects of successive judgments. This additional factor leads to a model of noise:

$$\begin{aligned} \text{Modulus noise} &= \text{CommonMode noise} + \text{EpsilonModulus noise} \\ \text{and} \\ \text{Object noise} &= \text{CommonMode noise} + \text{EpsilonObject noise} \end{aligned}$$

If we now add the assumption that the noise terms are symmetrically distributed we can see that the noise in a category judgment (cj) is not transformed:

$$\begin{aligned} \text{cj} &\approx [f(\text{Object}) + \text{Object noise}] - [f(\text{modulus}) + \text{Modulus noise}] \\ &= [f(O) - f(M)] + (\text{Object noise} - \text{Modulus noise}) \\ &= [f(O) - f(M)] + (\text{EpsilonObject noise} - \text{EpsilonModulus noise}) \end{aligned}$$

the last term of which is the untransformed noise, whereas the noise in a ratio judgment (rj) is log-transformed:

$$\log(\text{rj}) \approx \{\log[f(O) + \text{Object noise}]\} - \{\log[f(M) + \text{Modulus noise}]\}$$

and here the noise terms *are* transformed.

The Dotscope Program

Control file commands and format:

The control file ("dot program"), which is read by the main program ("dotscope"), determines the initial positions and directions of the targets on the video screen. Additionally, the control file determines when the various menus will appear and sets the maximum running time of the session.

There are six commands in the instruction set. These commands follow the following format:

field1,field2,field3,field4,...,fieldn

field1: The number of fields following in this line (equal to n1).

field2: The command number (from 1 to 6).

field3: The frame number when the next action will take place.

field4 to

fieldn: These fields contain the data required by the command specified in field 2.

The commands are listed according to the following scheme:

Name of command:

Purpose of the command.

field1,field2

field4: Description of the data for this field.

fieldn: Description of the data for this field.

The commands are:

Setdot/dly:

Sets the number of targets that will appear on the screen,
sets the delay between frames.

4,1

field4: Number of targets (1 to 20).

field5: Delay (in seconds).

MenuSel:

Selects the frame at which the option menus will appear.

5,2

field4: Altitude menu (stage 1).

field5: Collision avoidance method menu (stage 2).

field6: Frame at which the program ends.

Coord:

Specifies the initial coordinates of the target.

7,3

field4: Target number.

field5: X coordinate (0 to 600).

field6: Y coordinate (0 to 180).

field7: Z altitude (0 to 999).

field8: Airline number (1 to 20).

Vel:

Specifies the initial velocity of the target

6,4

field4: Target number.

field5: Delta X (number of pixels change per frame).

field6: Delta Y.

field7: Delta Z.

Util:

Activates the utility rating question.

3,5

field4: Type of utility question (1= subtask, 2= overall).

Laca:

Activates the "Low Altitude Collision Avoidance" signal.

2,6

Source Code

```
*****
**                                                                 **
**                               Dotscope                          **
**                                                                 **
**                               Thomas E. Wiegand                 **
**                                                                 **
**                               © 1987 Columbia University Psychophysics Laboratory **
**                               (Commodore Amiga 1000 S/N MX1178596) **
**                                                                 **
*****

*****
** control routine                                              **
*****

TIMER OFF

REM Initialize the system and program:
  GOSUB filename.init
  GOSUB register.init
  GOSUB disk.init
  GOSUB graphics.init

REM Set up the interrupt service subroutines:
  ON BREAK GOSUB bfin
  ON ERROR GOTO ror
  ON TIMER(delay) GOSUB runner
  ON MOUSE GOSUB altsay

REM Turn on the interrupts and wait:
  TIMER ON:MOUSE ON:BREAK ON
slp:
  SLEEP
  IF frame=MAXFRAMES GOTO fin
  GOTO slp

STOP
*****
```

```
*****
** timer interrupt subroutine                                     **
*****
```

runner:

```
MOUSE OFF:TIMER STOP
OBJECT.OFF:CLS
IF nfl=0 THEN GOTO runner.c
IF flag.coin=1 THEN GOSUB coincidence
IF flag.lch=1 THEN GOSUB latchx
winna=WINDOW(1)
FOR dot=1 TO maxdot
    GOSUB dot.update
    GOSUB dot.display
    GOSUB tail
NEXT dot
WINDOW OUTPUT winna
GOSUB crash
IF flag.dmeter=1 THEN GOSUB meters
OBJECT.ON
    frame=frame+1
```

runner.c:

```
    Read and act upon the various commands from the control matrix:
MENU STOP
IF frame = nfl THEN GOSUB n.frame.line :GOTO runner.c
IF frame = nf.altitude THEN GOSUB altitude
IF frame = nf.steer THEN GOSUB steer
IF frame = nf.end THEN GOTO fin
IF flag.ctrl=1 THEN MENU ON
```

MOUSE ON:TIMER ON

RETURN

```
*****
```



```

*****
** mouse interrupt subroutine                                     **
*****

altsay:
  'Determine which plane is being selected:
  LOCATE 21,60:PRINT ".";
  IF flag.altsay=0 THEN:RETURN
  dot.mouse=0
  i=MOUSE(0)
  FOR i=1 TO maxdot
    up=dot.y(i):dn=up+20
    lft=dot.x(i):rt=lft+40
    IF (MOUSE(2)>up AND MOUSE(2)<dn)AND(MOUSE(1)>lft AND MOUSE(1)<rt)
      THEN dot.mouse=i
  NEXT i

  IF dot.mouse=0 THEN say.in.a$="reepo":say.in.n=0:GOSUB sayit:RETURN
  say.in.a$=""
  say.in.n=dot.z(dot.mouse)
  GOSUB sayit

RETURN

*****

```

```

*****
** dot display subroutines (called by runner) **
*****

```

dot.update:

```

    'updates the coordinates of the planes
    dot.x(dot)=vect.x(dot)+dot.x(dot)
    dot.y(dot)=vect.y(dot)+dot.y(dot)
    dot.z(dot)=vect.z(dot)+dot.z(dot)

```

RETURN

dot.display:

```

    OBJECT.X dot,dot.x(dot)
    OBJECT.Y dot,dot.y(dot)
    IF vect.x(dot)>0 THEN GOTO df
    LOCATE (dot.y(dot)/9)+1,(dot.x(dot)/10)+3:GOTO dg
    df:db=(dot.x(dot)/10)6:IF flag.num=0 THEN db=db+4
    IF db<1 THEN db=1
    LOCATE (dot.y(dot)/9)+1,db
    dg:PRINT nom$(dot);
    IF flag.num=1 THEN PRINT dot.z(dot);

```

RETURN

tail:

```

    dx=vect.x(dot):dy=vect.y(dot):
    f=ATN(1*dy/((dx/3)+.0001))
    IF SGN(dx)=1 THEN nm=1 ELSE nm=-1
    ix=dot.x(dot)+1+12*COS(f)*nm
    iy=dot.y(dot)5*SIN(f)*nm
    f=dot+maxdot
    OBJECT.X f,ix:OBJECT.Y f,iy

```

RETURN

meters:

```

    WINDOW OUTPUT 6
    FOR mi=1 TO maxdot
        LOCATE mi,2
        PRINT nom$(mi)+": ";dot.z(mi);
    NEXT mi
    WINDOW OUTPUT 4

```

RETURN

coincidence:

```

    ia=1
    FOR ic=1 TO maxdot
        temp=dot.z(ic)

```

```

    FOR id=1 TO maxdot
        IF ic=id THEN GOTO ix
        IF temp=dot.z(id) THEN ia=ic:ib=id
        ix:
    NEXT id
NEXT ic
IF ia=1 THEN RETURN
OBJECT.SHAPE ia,reddot$
OBJECT.SHAPE ib,ia
RETURN

```

crash:

```

    ia=1
    FOR ic=1 TO maxdot
        temp=dot.z(ic)
        FOR id=1 TO maxdot
            IF ic=id THEN GOTO ixb
            IF temp=dot.z(id) THEN ia=ic:ib=id
            ixb:
        NEXT id
    NEXT ic
    IF ia=1 THEN RETURN
    IF NOT((dot.x(ia)+5>dot.x(ib)5)AND(dot.x(ib)+5>dot.x(ia)5)) THEN RETURN
    IF NOT((dot.y(ia)+3>dot.y(ib)3)AND(dot.y(ib)+3>dot.y(ia)3)) THEN RETURN
    zk:
    msg$="A fatal air incident has occurred."
    key$=msg$:GOSUB respond
    CLS
    BEEP
    PRINT key$;
    GOSUB dly
    CLS
    GOSUB outility
    GOTO fin
STOP

```

```
*****
** selection menu subroutines (called by runner) **
*****
```

altitude:

```
    stage one of the twopart task
    WINDOW 5,"Choose a method for displaying altitude information.",(1,1) (590,2),6
    MENU OFF:MENU RESET
    MENU 1,0,1,"altitude information display options"
    MENU 2,0,1,""
    MENU 1,1,1,"alphanumerics "
    MENU 1,2,1,"voice interrogation "
    MENU 1,3,1,"digital meters"
    key$="altitude display request on":GOSUB respond
    mu:IF MENU(0)=0 THEN GOTO mu
    i=MENU(1)
    key$="response: "+STR$(i):GOSUB respond
    IF i=2 THEN flag.altsay=1
    IF i=3 THEN flag.dmeter=1:WINDOW 6,"altitude",(1,1)(90,maxdot*10),18
        :WINDOW OUTPUT 4
    IF i=1 THEN flag.num=1
    asflag$="altitude"
    CLS
    WINDOW CLOSE 5
RETURN
```

steer:

```
    'stage two of the twopart task
    WINDOW 5,"Choose a method for averting a collision.",(1,1)(590,2),16
    MENU OFF:MENU RESET
    MENU 1,0,1,"collision avoidance options "
    MENU 2,0,1,""
    MENU 1,1,1," altitudedchange "
    MENU 1,2,1," lateralchange 12 degrees "
    MENU 1,3,1," lateralchange continuous "
    key$="steer menu request on":GOSUB respond
    mub:IF MENU(0)=0 THEN GOTO mub
    cmode=MENU(1)

    key$="response: "+STR$(cmode):GOSUB respond
    CLS
    IF cmode=1 THEN MENU 1,0,1,"increase":MENU 2,0,1," decrease ":GOTO gut
    IF cmode=2 OR cmode=1 THEN MENU 1,0,1,"left turn ":MENU 2,0,1,"right
        turn":
    GOTO gut
    IF cmode=3 THEN MENU 1,0,1,"left turn ":MENU 2,0,1,"right turn"
    gut:
```

```

IF cmode=1 OR cmode=2 OR cmode=3 THEN MENU 1,1,1,"activate "
                                         :MENU 2,1,1,"activate "

gu:
ON MENU GOSUB controller
WINDOW CLOSE 5
flag.ctrl=1
RETURN

controller:
dmode=MENU(0):MENU OFF:flag.ctrl=0
cd:'get the plane number
WINDOW 5,"Select a target to be acted upon.",(1,1)(590,12),2
ll:CLS
key$="target selection menu on":GOSUB respond
INPUT tgt$
key$="response: "+tgt$:GOSUB respond
tgtnom=1
FOR i=1 TO maxdot
    IF tgt$=nom$(i) THEN tgtnom=i
NEXT i
IF tgtnom=1 THEN CLS:PRINT"try again try again try again try again try
again":GOTO ll
key$="direction: "+STR$(dmode):GOSUB respond
CLS: WINDOW CLOSE 5
ON cmode GOSUB altch,velch,latch
RETURN
*****

```

```

*****
** dot modification subroutines (called by runner)
*****

```

altch:

```

    altitude change
    IF dmode=1 THEN fa=1 ELSE fa=-1
    dot.z(tgtnom)=dot.z(tgtnom)+fa*10
RETURN

```

velch:

```

    'velocity change
    'IF dmode=1 THEN fa=2 ELSE fa=.5
    'vect.x(tgtnom)=fa*vect.x(tgtnom)
    'vect.y(tgtnom)=fa*vect.y(tgtnom)
    'this is now 12 degree rotate!
    IF dmode=1 THEN fa=.2 ELSE fa=.2
    dx=vect.x(tgtnom)/3:dy=1*vect.y(tgtnom)
    vect.x(tgtnom)=3*(dx*COS(fa)+dy*SIN(fa))
    vect.y(tgtnom)=1*(dy*COS(fa)dx*SIN(fa))
RETURN

```

latch:

```

    flag.lch=1
RETURN

```

latchx:

```

    lateral direction change
    turn 12 degrees per frame
    IF dmode=1 THEN f=.105 ELSE f=.105
    dx=vect.x(tgtnom)/3:dy=1*vect.y(tgtnom)
    vect.x(tgtnom)=3*(dx*COS(f)+dy*SIN(f))
    vect.y(tgtnom)=1*(dy*COS(f)dx*SIN(f))
RETURN

```

```

*****

```

```

*****
** control matrix command service subroutines (called by runner)          **
*****

```

n.frame.line:

```

    nfl=info(count,1)
    ON info(count,0) GOSUB dot.num, option.frm, dot.coord, dot.vel, util.num,
        laca.num
    count=count+1

```

RETURN

option.frm:

```

    nf.altitude=info(count,2):nf.steer=info(count,3):nf.end=info(count,4)

```

RETURN

dot.coord:

```

    n=info(count,2)
    dot.x(n)=info(count,3)
    dot.y(n)=info(count,4)
    dot.z(n)=info(count,5)
    nom$(n)=alin.noma$(info(count,6))

```

RETURN

dot.vel:

```

    n=info(count,2)
    vect.x(n)=info(count,3)
    vect.y(n)=info(count,4)
    vect.z(n)=info(count,5)

```

RETURN

util.num:

```

    IF info(count,2)=2 THEN GOTO outility
    ub$="Please rate the utility of your choice."
    IF frame>nf.steer THEN ub$=ub$+modcoll$ ELSE ub$=ub$+modalt$
    WINDOW 5,ub$(10,1)(590,12),16
    GOSUB utility
    CLS:WINDOW CLOSE 5

```

RETURN

laca.num:

```

    BEEP

```

RETURN

dot.num:

```

    maxdot=info(count,2)
    GOSUB graphics.init

```

```
delay=info(count,3)
TIMER OFF:ON TIMER(delay) GOSUB runner:TIMER ON
RETURN
*****
```



```
*****
** utility subroutines                                     **
*****
```

utility:

```
'asflag$ has steering, altitude or final"
key$="utility question on":GOSUB respond
INPUT i$
key$="response: "+i$:GOSUB respond
RETURN
```

outility:

```
os$="Please rate the overall utility of your choices."+modover$
WINDOW 5,os$(10,1)(590,12),16
key$="overall utility question":GOSUB respond
INPUT i$
key$="response: "+i$:GOSUB respond
CLS: WINDOW CLOSE 5
RETURN
```

sayit:

```
a=say.in.n
'a has the numeric variable to be spoken
a2=0: out$=""
FOR i= 1 TO 3
  a3= a/(10^i): a3= a3 INT(a3)
  a2= 10 * a3 (a2/10)
  out$(i)= CHR$(48+a2)
NEXT i
FOR i= 3 TO 1 STEP 1
  out$= out$ + out$(i)
NEXT i
out$=say.in.a$+out$
SAY TRANSLATE$(out$)
RETURN
```

respond:

```
rcount=rcount+1
resp$(rcount,0)=STR$(frame)
GOSUB get.time
resp$(rcount,1)=tim$:resp$(rcount,2)=key$
RETURN
```

get.time:

```
tim$=TIME$
RETURN
```

dly:

'delay

FOR dy=1 TO 4000:NEXT dy

RETURN

```
*****
** initialization subroutines                                     **
*****
```

filename.init:

```
'modulus cues
  modalt$="(1500)"
  modcoll$="(60)"
  modover$="(250)"
'drive and directory names
  ddrive$="dotscope:"
  rdrive$="response:":'can be changed so that subject
    data can go on another disk
  plane$=ddrive$+"Bobs/sq3210"
  redplane$=ddrive$+"Bobs/sqred"
  tail$=ddrive$+"Bobs/sq1505"
  script$=ddrive$+"DotPrograms/"
  resp$=rdrive$+"Responses/"
```

RETURN

register.init:

```
DIM dot.x(20),dot.y(20),dot.z(20),nom$(20),alin,noma$(20)
DIM vect.x(20),vect.y(20),vect.z(20),info(50,6)
DIM resp$(20,2):rora=0
MAXFRAMES=30: XRES=600: YRES=180
frame=0: count=0: rcount=0 :dmode=0:cmode=0
flag.num=0:flag.altsay=0:flag.coin=0:flag.dmeter=0
flag.lch=0
```

RETURN

disk.init:

```
maxdot=0: delay=1
nf.altitude=1: nf.steer=1: nf.end=0: nfl=0
'airline name list:
  alin.noma$(1)="ta":alin.noma$(2)="nw"
  alin.noma$(3)="pe":alin.noma$(4)="aa"
  alin.noma$(5)="ua":alin.noma$(6)="lu"
  alin.noma$(7)="ba":alin.noma$(8)="ea"
  alin.noma$(9)="co":alin.noma$(10)="tw"
  alin.noma$(11)="sa":alin.noma$(12)="de"
  alin.noma$(13)="al":alin.noma$(14)="qa"
  alin.noma$(15)="mo":alin.noma$(16)="fr"
  alin.noma$(17)="ge":alin.noma$(18)="ch"
  alin.noma$(19)="19":alin.noma$(20)="20"
  SAY TRANSLATE$(" "):'gets the voice synthesis routine from disk
  count=0
  'prompt for file names for this run
```

```

CLS
PRINT"d<>r<>"
INPUT i$
red$=i$
INPUT response$
rer$=response$
PRINT:PRINT"loading " :";script$+i$;" .dot"
OPEN "i",#1,script$+i$+" .dot"
WHILE NOT EOF(1)
    FOR i=0 TO 6
        info(count,i)=0
    NEXT i
    INPUT #1,m$
    m=VAL(m$)
    FOR i=0 TO m1
        INPUT #1,mi$:info(count,i)=VAL(mi$)
    NEXT i
    count=count+1
WEND
CLOSE #1
count=0
CLS
response$=resp$+response$+" .resp"
PRINT"The response data will be stored in file:"
PRINT"";response$
FOR i=0 TO 10
    FOR j=0 TO 3
        resp(i,j)=0
    NEXT j
NEXT i
GOSUB dly
CLS
resp$(0,0)=STR$(frame):GOSUB get.time:resp$(0,1)=tim$:'program timing
    starts now"
resp$(0,2)="START"
RETURN

graphics.init:
WINDOW 4,"Kennedy International Airport":,(1,1)(600,185),20
CLS
OPEN plane$ FOR INPUT AS 1
OBJECT.SHAPE 1,INPUT$(LOF(1),1)
CLOSE 1:OBJECT.PRIORITY 1,32766
FOR dot=2 TO maxdot
    OBJECT.SHAPE dot,1 :OBJECT.PRIORITY dot,32767dot
NEXT dot

```

```
OPEN tail$ FOR INPUT AS 1
OBJECT.SHAPE maxdot+1,INPUT$(LOF(1),1)
CLOSE 1
OBJECT.PRIORITY maxdot+1,32767
FOR dot=maxdot+2 TO 2*maxdot
    OBJECT.SHAPE dot,maxdot+1
    OBJECT.PRIORITY dot,32767-dot
NEXT dot
OPEN redplane$ FOR INPUT AS 1
reddot$= INPUT$(LOF(1),1)
CLOSE 1
RETURN
```

```
*****
** exit subroutines(called from runner & error/break interrupts) **
*****
```

bfin:

```
'break was encountered
TIMER STOP:MOUSE OFF:MENU RESET
CLS
WINDOW CLOSE 4:WINDOW CLOSE 5:WINDOW CLOSE 6
PRINT"Response file ";response$;" not written."
PRINT"This run has been aborted."
GOSUB dly
GOTO fz
```

ror:

```
'error trap
rora=1
```

fin:

```
exit subroutine
TIMER OFF:MOUSE OFF:MENU RESET
CLS
WINDOW CLOSE 4:WINDOW CLOSE 5:WINDOW CLOSE 6
CLS
PRINT"writing the response file"
OPEN response$ FOR OUTPUT AS #1
WRITE #1,red$,rer$
FOR i=0 TO rcount
    WRITE #1,resp$(i,0),resp$(i,1),resp$(i,2)
NEXT i
IF rora=0 THEN GOTO skf
WRITE #1,"ERROR:",STR$(ERR)
WRITE #1,STR$(frame),STR$(dot),STR$(flag.ctrl)
WRITE #1,STR$(dot.x(dot)),STR$(dot.y(dot)),STR$(dot.z(dot))
```

skf:

```
WRITE #1,"end of file",STR$(frame)
CLOSE #1
'OPEN ddrive$+"r.info" FOR INPUT AS 1
'OPEN response$ FOR OUTPUT AS 2
'WRITE #2,INPUT$(LOF(1),1)
'CLOSE 2 : CLOSE 1
```

fb:

CLS

'SYSTEM

STOP

END